SODIUM DISTRIBUTION OF PARTIALLY MOLTEN PLANETESIMALS INFERRED FROM METEORS AND METEORITES. T. Arai[1], M. Komatsu[2], K. Otsuka[3], T. Kasuga[4], [1]Planetary Exploration Research Center (PERC), Chiba Institute of Technology, 2-17-1 Tsudanuma, Chiba 275-0016, Japan, (tomoko.arai@it-chiba.ac.jp), [2]Waseda University, Tokyo, Japan 169-8050, [3]Tokyo Meteor Network, 1-27-5 Daisawa, Tokyo 155-0032, Japan, [4]National Astronomical Observatory of Japan, 2-21-1 Osawa, Tokyo 181-8588, Japan.

Introduction: Primitive achondrites have bulk chemical compositions relatively close to those of chondrites, but affected by incipient partial melting proccese to some extent. They record chemical and physical state of the earliest melting on planetesimals. We studied chemical effect of partial melting of planetesimals by mineralogical study of primitive achondrites and astronomical observation of meteor showers whose parent bodies are asteroids.

Samples & methods: LL-type ordinary chondrites of different equilibration degree, Yamato(Y) 792772 (LL4), Y75258 (LL6), and Y82067 (LL7) were provided by National Institute of Polar Research of Japan (NIPR). Uusual primitive achondrite, LEW 86220 [1] was provided by the Antarctic Meteorite Working Group, and Caddo County with silicate inclusions [2] by Prof. H. Takeda of Chiba Institute of Technology (Chitech). Mineralogical analyses were conducted with a JEOL JSM-6510 analytical SEM of PERC/Chitech, a JEOL JXA-8200 EPMA of NIPR, and JEOL JXA-8900 EPMA of Waseda University.

Results:

LEW 86220 consists of fine-grained acapulcoitic lithology and coarse-grained gabbroic lithology with smooth embayed boundaries in between. The former lithology includes olivine, orthopyroxene, plagioclase ($An_{14.7\text{-}16.8}Or_{3.4\text{-}4.5}$) of 100-250 µm, troilite and FeNi metal. The modal abundance is broadly chondritic with <10% plagioclase. The latter has coarse-grained (up to 7 mm across) plagioclase ($An_{9.5\text{-}18.8}Or_{3.1\text{-}6.5}$) (64%), chromian diopside (up to 2.5 mm across) (15 vol.%), with minor FeNi metal, troilite, phosphate.

Silicate inclusion in Caddo County consists of coarse-grained gabbroic lithology, fine-grained mafic-rich lithology, and metal-rich lithology. Mineral compositions are constant among the lithologies. The gabbroic lithology has coarse-grained (up to 9 mm across) plagioclases ($An_{16.5\text{-}18.2}Or_{2.9\text{-}3.3}$) (59%), enclosing chromian diopsides (28%) with smaller (<1 mm across) orthopyroxene (5%) and olivine (7%). The metal-rich lithology in direct contact with the gabbroic lithology includes rounded isolated grains of plagioclase and diopside. The mafic-rich lithology contains finer-grained (≦1 mm across) olivine, orthopyroxene and diopside with less amount of plagioclase (~10%).

Y792772 contains abundant chondrules with coarse-grained olivine and pyroxene of up to a few mm across. Anorthite plagioclase mostly occurs within chondrules. Y75258 includes relict chondrules and coarse-grained (a few hundreds µm across) equigranular olivines in fine-grained recrystallized matrices of olivines with FeS and FeNi in the grain boundary. Y82067 shows granoblastic texture including fine-grained polygonal grains of olivine and pyroxene with plagioclase, chromite, and metal. Chondrules are rarely found. FeS-FeNi metal are locally segregated.

Figure 1 indicates color composite elemental maps of Fe, Mg, and Na. Among the three chondrites with different equilibration degree, the distribution of the three elements are generally homogeneous within the scale of thin section. In contrast, the elemental distribution is inhomogeneous in LEW 86220 and Caddo County, especially Na and Fe within the thin sections. Na-rich phases and Fe-rich phases are much coarser-grained than Mg-rich phase. Mg-rich phases are recrystallized chondritic materials and/or residual phases, while Fe-rich phase and Na-rich phases are metallic and silicate partial melts. The elemental maps indicate that parital melting cause inhomogeneous distribution of Na and Fe in the millimeter and centimeter scale.

Discussions:

Among the LL chondrites, not much difference in modal abundance and elemental distribution is observed, despite the textural differences. In contrast, the both primitive achondrites show remarkable modal and elemental difference among the distinct lithologies. Gabbroic lithologies represent silicate partial melts generated by an incipient melting of chondrites. Low-degree partial melting of chondrites generate nearly peritectic composition of Fo-An-Qz system with ~ 55% plagioclase, which is broadly consistent with the modal abundance of plagioclase in the gabbroic lithologies. Plagioclase-rich silicate partial melts co-exist with FeNi-FeS melts and residues within the scale of 1 cm. Chondrites with <10 vol% plagioclase has NaO<1 wt% (0.2-0.6 wt%). A silicate partial with 60 vol% plagioclase has 5.4 wt% NaO, while the residues likely show NaO≪1 wt%, probably <0.1 wt%. Partial melting causes local Na variation of one or two order of magnitude.

An extreme Na depletion relative to the solar abundance is reported for the Geminid meteor shower [3-5], whose parent is a B-type [6], active asteroid [7-8], 3200 Phaethon. As the dust grain size is 1-10 mm [9], the Na depletion occurs in the mm-cm scale, which is consistent with the above mineralogical observation. Na depletion observed for meteor showers with a perihelion distance of < 0.1 AU, is likely caused by solar heating [4]. Since that of the Geminid meteor shower (0.14 AU) exceeds 0.1 AU, the Na depletion could be due to the chemical signature of the parent Phaethon, which may represent a partially-molten planetesimal.

References: [1] McCoy T. J. et al. (1997) *GCA 61*, 639. [2] Takeda H. et al. (2000) *GCA 64*, 1311. [3] Kasuga T. et al. (2005) *A&A 438*, L17. [4] Kasuga T. et al. (2006) *A&A 453*, L17. [5] Torigo-Rodriguez J. M. et al. (1993) *MPS 38*, 1283. [6] Whipple F. L. (1983) *IAU Circular* 3881. [7] Jewitt D. & Li, J. (2010), AJ, 140, 1519 [8] Jewitt D. et al. (2013) *ApJL*, 771, L36. [9] Borovicka J. B. et al (2010) *Proc. IAU Symp.263*, 218.

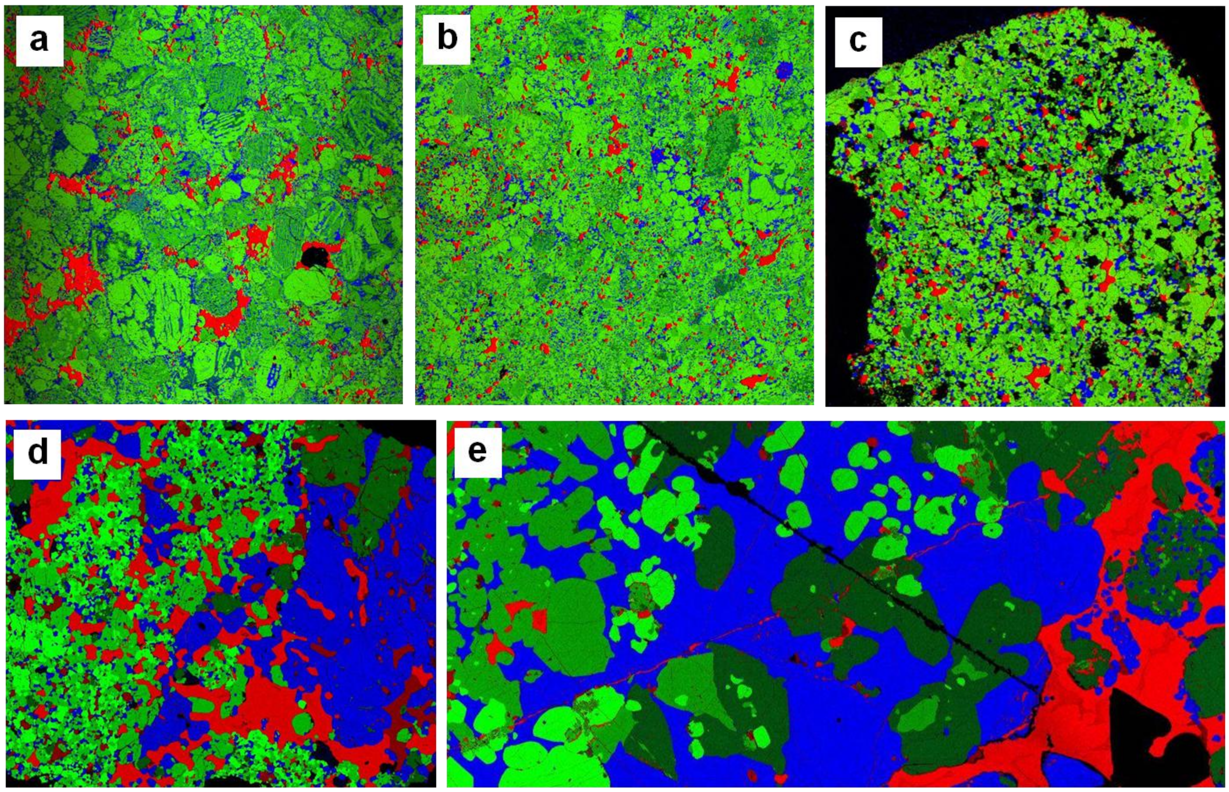

Fig. 1. Color composite elemental maps (Red: Fe, Green: Mg, Blue: Na) of (a)Y-792772 LL4 chondrite (FOV: 7 mm), (b) Y-793506 LL6 chondrite (FOV: 8 mm), (c) Y-82067 LL7 chondrite (FOV: 4 mm) (d) LEW 86220 acapulcoiite-lodranite (FOV: 9 mm) and (e) silicate inclusion of Caddo County IAB iron (FOV: 15 mm). Red indicates FeNi metal and troilite, bright green shows olivine and orthopyroxene, dark green shows diopside, and blue indicates Na-rich plagioclase.